Fatigue and Crack Propagation Analysis of Mechanically Fastened Joints

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Abstract

THE results of an investigation on the development of analytical methods for predicting fatigue crack initiation and propagation in mechanically fastened metallic joints are presented herein Comparisons between analytical results and limited experimental data indicate that the overall prediction capability of current analytical methods can be improved by realistically modeling the loading condition the crack initiation mechanism and the crack propagation mechanism

Contents

This paper describes an analysis procedure for predicting the life of precracked mechanically fastened joints Specific configurations considered are double and single shear joints such as those shown in Figs 1 and 2 respectively Analytical results are compared with actual experimental results ob tained from the open literature [1] It should be noted that the test results reported in Ref 1 are the only suitable ex perimental data currently available in the literature and represent a rather limited data base However, the conclusions arrived at in this paper offer a state of the art approach toward better understanding of crack initiation and growth behavior in mechanically fastened joints

All of the specimens reported in Ref 1 were fabricated from 7075 T6 aluminum alloy and assembled with steel hi lok fasteners The fasteners were installed in close tolerance fit holes with finger tight clamp up torque Each specimen contained a primary 1 27 mm (0 050 in) quarter circular corner crack located at the faying surface of each structural element of the joint at a selected fastener hole (hole 3 of row 2 in the double shear joint specimens or hole 4 of row 1 in the singular shear joint specimens) Several specimens also contained continuing damage flaws (CDFs) as specified in MIL A 83444 at the adjacent holes A maximum remote stress of 117 2 MPa with a stress ratio of 0 1 (constant am plitude) was applied in all tests Crack growth and crack initiation were monitored at these fastener holes, i e the hole with the primary crack and the adjacent holes in the same row (with or without CDFs)

The analytic methods described herein involve essentially the same assumptions and computational steps as those reported in Ref 1 Crack growth and crack initiation life predictions were performed for the doublers of the double shear joint and the skin of the single shear joint The effects of cracks in other elements (of the same specimen) the continuing damage flaws and faying surface friction were ignored in the analyses Parallel calculations were performed to determine the growth history of the primary crack in ad dition to the initiation and growth history of the secondary crack Interaction effects between the primary and secondary cracks were accounted for in the analyses The following outline itemizes the major differences in methodology be tween Ref 1 and the methodology described herein

1) The analytic results represented herein used a set of two dimensional stress intensity factors for the corner crack whereas a one dimensional analysis was performed in Ref 1 This two dimensional analysis procedure allows one to separately calculate the crack growth rate at each crack tip and monitor the change in crack shape during crack propagation The transition of a corner crack to a through the thickness crack can therefore be modeled more accurately

2) After a secondary crack initiated at the diametrically opposite side of the primary crack the analysis methodology described in this paper considered the new crack con figuration as a line crack subjected to combined point loading and far field loading

3) Stress severity factors, for crack initiation analysis were modified to reflect the fastener load distributions in the mechanically fastened joints

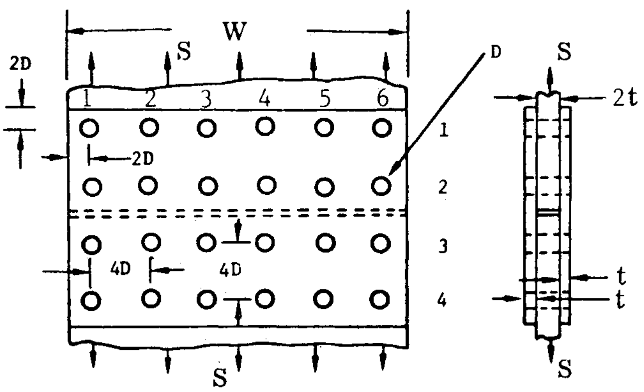

Fig 1 Double shear joint specimen configuration

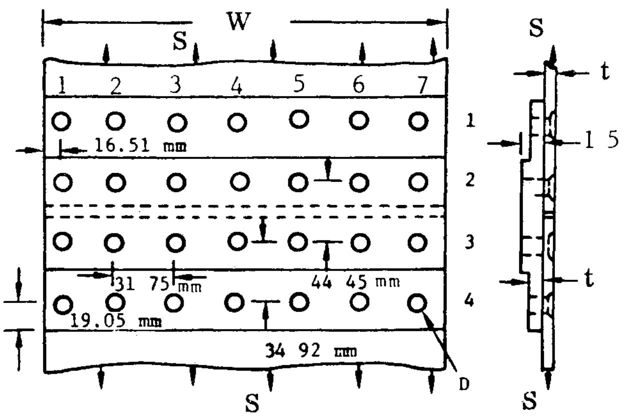

Fig 2 Single shear joint specimen configuration

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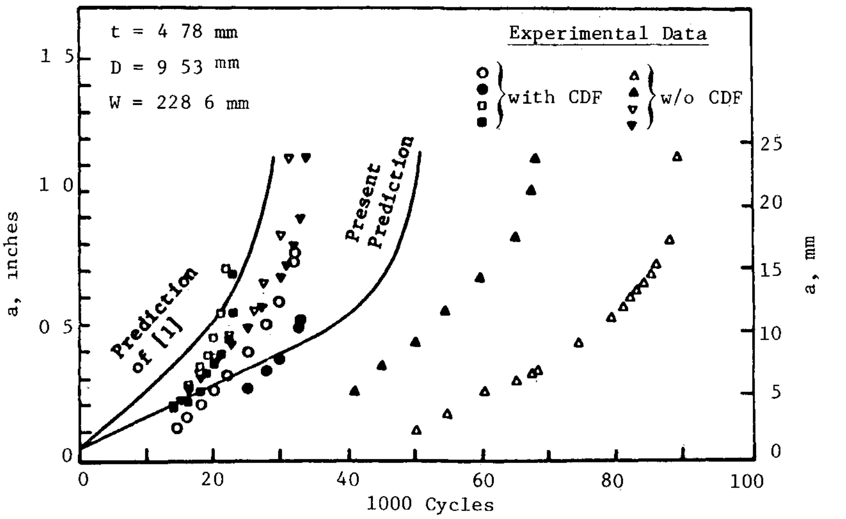

Fig 3 Comparison of thick double shear joint specimen predictions and experimental data

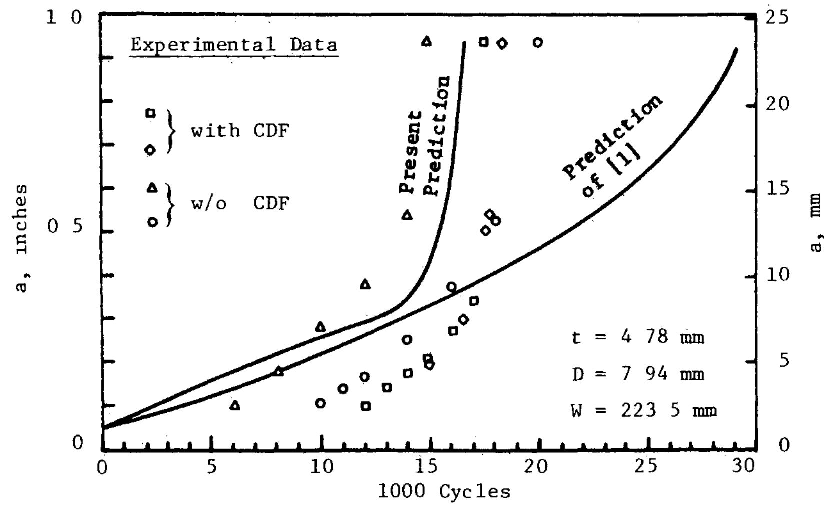

Fig 4 Comparison of single shear joint specimen predictions and experimental data

4) Instead of using the conventional Miner's rule for fatigue damage accumulation and setting an arbitrary crack size for the secondary crack the work described in this paper implemented a crack initiation analysis procedure that clearly defines the event of secondary crack initiation The improved method accounts for a nonstationary configuration (as a function of the pre existing, continuously growing crack) determines the size of the newly initiated crack (at any selected location), and the size of the primary crack at the time the secondary crack is initiated

Analytic results based on the methods presented in this paper along with the existing predictions and experimental data of Ref 1 are presented in Figs 3 and 4 The following clarifies a few points regarding the test data and predictions

1) All predictions and experimental data points represent the growth of the primary crack across the ligament toward the adjacent hole in front of the crack Although not shown in the figures the growth histories of the secondary cracks were computed

2) Due to geometric symmetry of the double shear joints cracks in each doubler exhibited identical behavior; therefore, only one analysis (representing both doublers) is presented The solid symbols denote experimental data points for a crack in one doubler, whereas the open symbols of the same kind refer to the other doubler of the same specimen

3) Experimental data were obtained from external surfaces of the specimens Predictions were however performed for cracks at the faying surfaces of the specimens

In summary, the analytic predictions based on the procedures outlined in this synoptic correlate reasonably well with experimental data The analytical methods of Ref 1 however, provide conservative predictions for double shear joint specimens and unconservative predictions for the single shear specimens

References

[1]Brussat T R Chiu, S T , and Creager M , Flaw Growth in Complex Structure AFFDL TR 77 79 Dec 1977